

Vacuum requirements for the cooling section in the Recycler

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Recycler vacuum considerations

- The electron cooling section should not be different from an average Recycler vacuum sector.
- The design Recycler pbar lifetime >200 hours (with cooling) and the 95%, norm. emittance growth rate 2 $\mu\text{m/hr}$. The measured acceptance in both planes is greater than 40 μm (norm.).
- The average beta function in both planes is about 40 m. The max. vertical beta-function is 85 m at two locations, 15 m upstream and downstream of the cooling section.
- For this average beta-function and acceptance values, the ratio of nuclear-to-coulomb loss cross-section is (for a zero-emittance beam):
 - Hydrogen: $\sigma_{\text{nH}}=40 \text{ mb}$, $\sigma_{\text{CH}}=33 \text{ mb}$, $\sigma_{\text{n}}/\sigma_{\text{C}}=1.3$
 - Nitrogen: $\sigma_{\text{nN}}=420 \text{ mb}$, $\sigma_{\text{CN}}=Z^2 \sigma_{\text{CH}}=1.6 \text{ b}$, $\sigma_{\text{n}}/\sigma_{\text{C}}=0.26$

Emittance growth calculation

$$\text{MeV} := 1.6 \cdot 10^{-13} \cdot \text{J}$$

$$m_p := 938 \text{ MeV}$$

$$m_e := .511 \text{ MeV}$$

$$\beta_{\text{ave}} := 40 \cdot \text{m}$$

$$\gamma := 9.5$$

$$r_p := 1.54 \cdot 10^{-18} \cdot \text{m}$$

$$c := 3 \cdot 10^8 \cdot \frac{\text{m}}{\text{s}}$$

$$\mu\text{m} := 10^{-6} \cdot \text{m}$$

$$Z := 7$$

$$A := 14$$

$$n := 1 \cdot 10^7 \cdot \frac{1}{\text{cm}^3}$$

$$V := 1 \cdot \text{m}^3$$

$$p := \frac{n \cdot V}{2.3 \cdot 3 \cdot 10^{22}}$$

$$p = 1.515 \times 10^{-10} \text{ Torr -- average pressure}$$

Emitt. growth rate:

$$D := \frac{12 \cdot \pi}{\gamma} \cdot \beta_{\text{ave}} \cdot c \cdot (r_p)^2 \cdot n \cdot Z \cdot (Z + 1) \cdot \ln \left[38360 (A \cdot Z)^{-0.333} \right]$$

$$D = 2.055 \frac{\mu\text{m}}{\text{hr}} \quad - 1-D, 95\% \text{ norm emittance growth rate}$$

Recycler vacuum requirements for the cooling section

- The N₂-equivalent pressure in the cooling section should be 1.5E-10 Torr with the electron beam ON at 500 mA.
- The vacuum in the cooling section should be well isolated from the Pelletron tubes to avoid pressure spikes during HV sparks.
- Due to difficulties of removing and installing solenoid modules, there should be redundancy in both the bake-out heating elements and temperature controls.